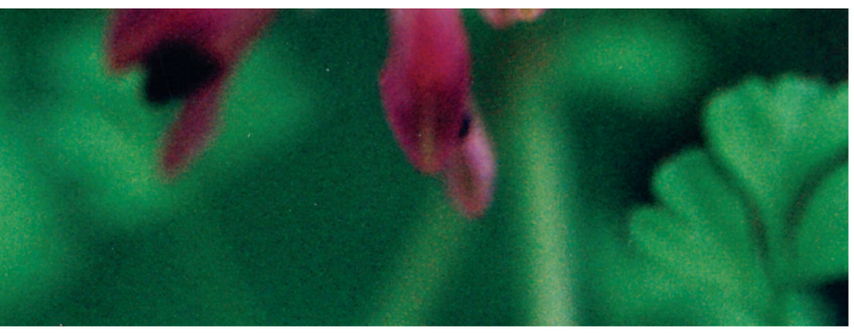
Soil microbes and the war on garden weeds

Weeds are a big problem to all gardeners and growers, especially if they do not want to use chemical herbicides. **Robert J. Kremer** explains how microbes can provide an effective, alternative means of control.

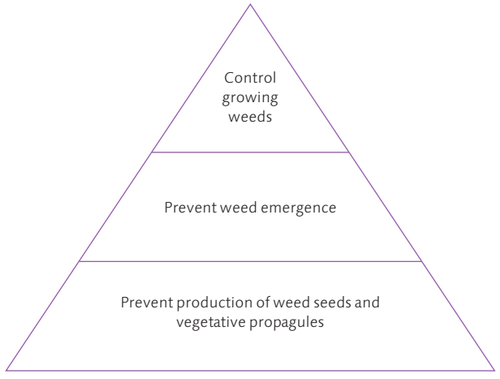


Weeds have been associated with human activity from the very beginnings of society, when man evolved from a hunter-gatherer mindset and began to domesticate plants and animals and cultivate the land on which he settled. Why have weeds continued to persist as problems in our gardens, lawns, fields, meadows, and roadsides to this day? What is the nature of weeds that causes them to be opportunistic in almost any environmental situation and pose problems ranging from competition with man's desirable plants, to production of allergens, production of complex chemicals often toxic to man and animal, contamination of foods, feed and fibre, and harbouring other pests? In today's society it seems to be easier to find a 'quick fix' for problems rather than try to understand why the problem exists and derive a management plan based on knowledge.

Because estimated costs of losses due to weeds are likely to exceed $10 billion annually, the simplest way to get rid of them is treat with herbicides and the problem disappears – for this year – only to return again the following spring. The majority of farmers, gardeners and others involved in land management only see the growing plant that needs control; they do not realize the dynamics of the entire life cycle of a weed. The larger and fundamental part of the weed problem lies in the soil as resident and viable seeds or other vegetative propagules (e.g. bulbs, rhizomes, etc.). In fact a total weed management approach is based on preventing seed production to relieve pressure on stopping weed emergence and control of the growing weed (Fig. 1). If weeds can be controlled at the seed stage, we can avoid total reliance on herbicides for controlling them when actively growing.

Weed seeds in soils

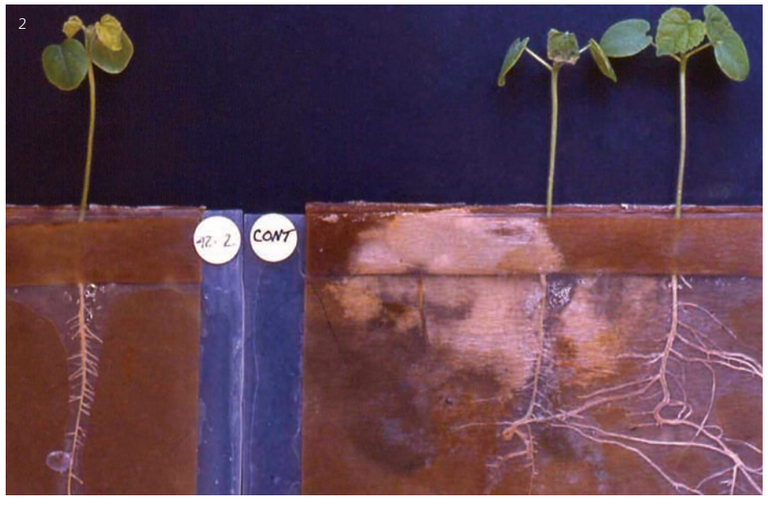
Most weeds produce great quantities of seeds that are dispersed to the ground where they eventually find their way into the upper few centimetres of the soil. These seeds have physiological traits that allow them to persist in a viable state (dormancy) in the soil for 50 years or more. Not all of them germinate every year, so weed problems can continue even if one manages to control seed production of weeds for several years! Why do weed seeds persist in soil without being attacked and decayed by the millions of micro-organisms typically inhabiting the soil? Based on many trials involving tedious retrieval of weed seeds from soil and culturing the associated micro-organisms, we found that many weed seeds possess elaborate mechanisms for avoiding microbial attack.

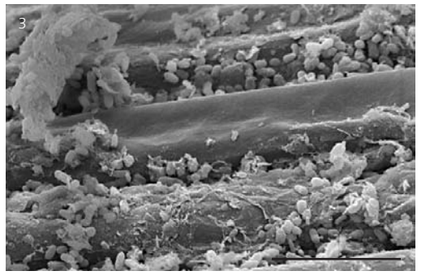


◀ Opposite page. Fumitory (*Fumaria* sp.), a beautiful flower, but an annoying weed for many gardeners. *Ian Atherton, SGM*

▲ Remains of the flower heads of a species of thistle, a common field weed. *Ian Atherton, SGM*

◀ Fig. 1. The three-part total weed management programme for crop or garden production systems, based on critical phases during the life history of a weed. *Reproduced with permission from R.J. Aldrich & R.J. Kremer (1997) Principles in Weed Management (Ames, IA: Iowa State University Press)*





Seeds with hard and dark-coloured coats (such as mallow), pose not only a physical barrier to attack by micro-organisms, but can also release toxic chemicals from their coats in soils at an optimum water content that repel or even kill soil micro-organisms. We have also found that some weed seeds harbour bacteria on or in the seed coat that are antagonistic to soil microbes.

Selection of 'seed-attacking' micro-organisms, therefore, would be a difficult task considering the nature of weed seed structure and chemistry. Some scientists have suggested that other organisms such as surface-dwelling insects might pierce seeds during feeding and allow entry of micro-organisms for attack. This strategy may work for only a few weed species and it is difficult to maintain adequate numbers of such beneficial insects in the field or garden to have a significant effect on depleting the seed population in soil.

Soils managed in a sustainable manner have more potentially weed-suppressive bacteria than soils managed under conventional systems that rely on high inputs of chemicals

▲ Fig. 2. Inhibition of velvetleaf (*Abutilon theophrasti*) seedling growth by inoculation with deleterious rhizobacteria (left). Note the much more extensively branched root system of the non-inoculated plant (right). The inoculated plant also shows evidence of chlorosis in the newest leaves. *R.J. Kremer*

▲ Fig. 3. Root surface of a 2-week old velvetleaf root colonized by *Pseudomonas fluorescens* strain 239 cells (arrow) aligned in the intercellular spaces of root epidermal cells. Bar, 10 µm. *R.J. Kremer*

▶ Fig. 4. Suppression of weeds in sweetcorn plots after 2 years of compost amendments added to soil compared to no treatment (inset). Weed density and biomass of the composted plot was reduced by >50 %. *R.J. Kremer*

▶ Opposite page. Rosebay willowherb (*Chamaenerion angustfolium*) growing in a farmer's field. *Ian Atherton, SGM*

Weed seedlings are vulnerable

The germinating seed is a considerably more favourable target for microbial attack than the actual seed. We have selected numerous bacterial cultures from roots of weed seedlings that show excellent growth inhibition under favourable conditions (Fig. 2). It is critical that the bacteria recognize the weed seedling root via chemical signalling and establish high populations on the root surface through aggressive colonization (Fig. 3). Drawbacks to this approach have been that application of selected bacterial cultures in practical fields and gardens is hampered by adverse environmental conditions (moisture and temperature stress) and that while bacteria are adapting to the soil environment, the weed seedling simply outgrows any inhibitory effect. Also, it is nearly impossible to develop an inoculant able to attack the broad spectrum of weed species that often infest our fields and gardens.

Conservation biological control approach

Because it has proved difficult to select micro-organisms for release into fields and gardens to successfully attack weed seeds and seedlings, perhaps the resident microflora can be induced to suppress weed seedling growth? We know from previous reports that the application of aged composts or manures to soils often suppresses soil-borne diseases of our desirable plants. Using this strategy, we have found that soils that have been managed in a sustainable manner, such as in organic gardening, have more potentially weed-suppressive bacteria than soils managed under conventional systems that rely on high inputs of chemicals. We tested this observation by applying different composts and manures (12–15 Mg ha^{-1}) and mulches of cover crops such as hairy vetch and oats, and assessed microbial activity and weed density. We found that after 2 years, soil organic matter levels increased as well as several soil microbial enzyme levels, which were directly related to reduced weed density (Fig. 4). The important finding is that a farmer or gardener able to recognize that weed seeds reside in soil can control future infestations by using some simple practices that stimulate populations of weed-seed- and seedling-attacking micro-organisms. No added exotic microflora, no expensive, hazardous chemicals are required – just patience in conserving and nurturing the naturally occurring weed biological control agents that reside directly in their own soil.

Robert J. Kremer
USDA ARS, 302 ABNR Building, University of Missouri, Columbia, MO 65211, USA. (t +1 573 882 6408; f +1 573 884 5070; e KremerR@missouri.edu)

Further reading

Aldrich, R.J. & Kremer, R.J. (1997). *Principles in Weed Management*. Ames, IA: Iowa State University Press.

Kremer, R.J. (1993). Management of weed seed banks with micro-organisms. *Ecol Applic* **3**, 42–52.

Kremer, R.J. & Li, J. (2003). Developing weed-suppressive soils through improved soil quality management. *Soil Till Res* **72**, 193–202.

Magdoff, F. & Weil, R.R. (2004). *Soil Organic Matter in Sustainable Agriculture*. Boca Raton, FL: CRC Press.